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(54) ATOMIZATION BURNER WITH FLEXIBLE FIRE RATE

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F23D 11/00 (2006.01)

(52) **U.S. Cl.**

CPC ***F23D 11/001*** (2013.01); ***F23D 11/10*** (2013.01); *F23D 2200/00* (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC F23D 11/001; F23D 11/10; F23D 2200/00; F23D 2202/00; F23N 2027/06

(Continued)

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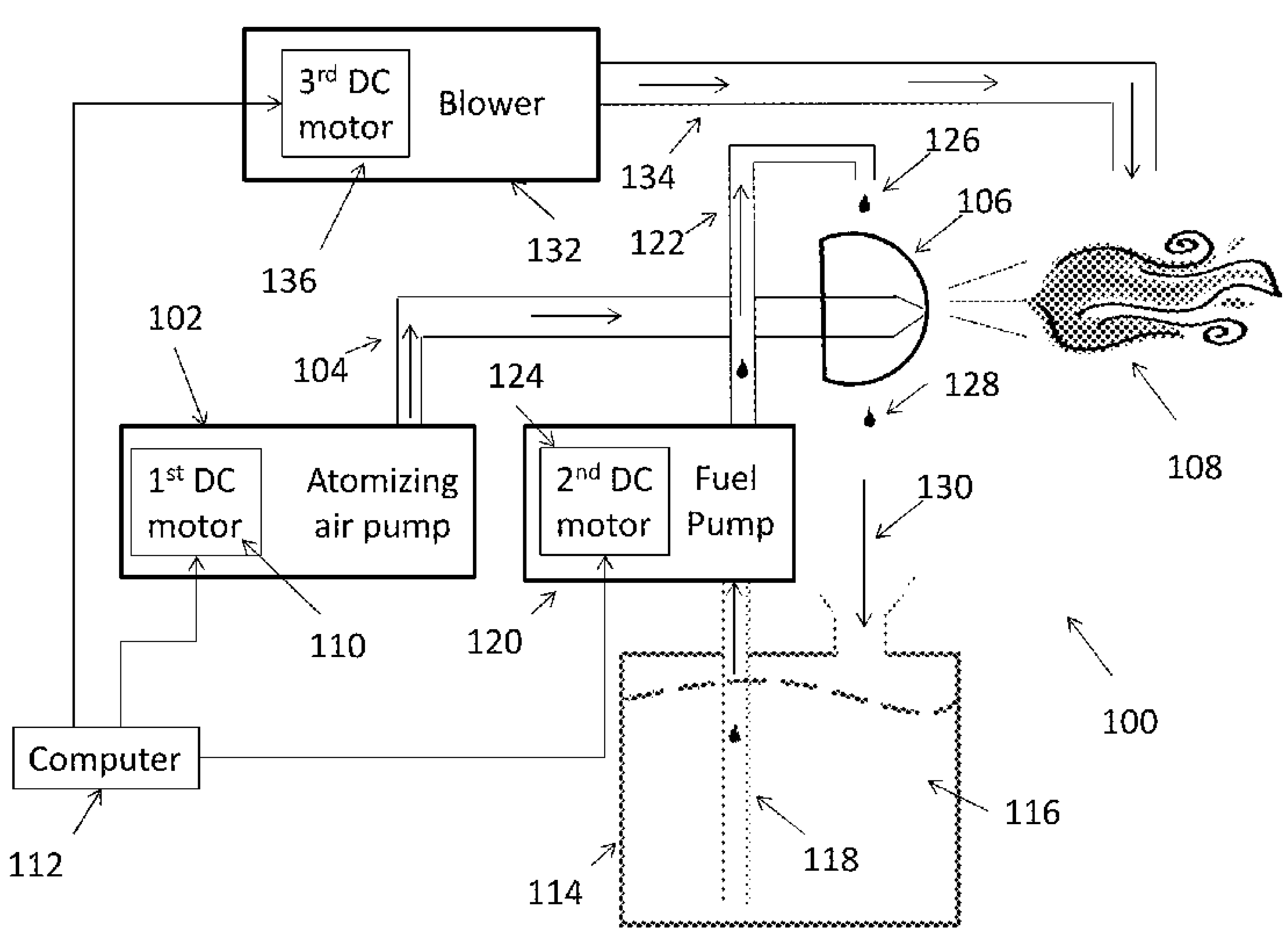
(57) **ABSTRACT**

An atomizing burner and corresponding method for turning an atomizing burner from an ON state to an OFF state. The burner has independently controllable flows of atomizing air, combustion air, and fuel flow, the burner in the ON state having flow values of burner parameters including flow of atomizing air, flow of combustion air, and fuel flow. The method includes: changing, in response to an OFF instruction, flow of at least one of the flow of atomizing air, combustion air and/or fuel to a lower non-zero value; first discontinuing, after a first period of time since the changing, flow of fuel and flow of atomizing air; maintaining, for a second period of time since the first period of time, flow of combustion air; second discontinuing, after the maintaining, flow of combustion air; wherein the maintaining prevents buildup of excess heat inside the burner during the transition to the OFF state.

12 Claims, 13 Drawing Sheets



(52) **U.S. Cl.**
CPC *F23D 2202/00* (2013.01); *F23D 2208/005* (2013.01); *F23N 2027/06* (2013.01)

(58) **Field of Classification Search**
USPC 431/6, 12
IPC F23D 11/10
See application file for complete search history.

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Fig. 1

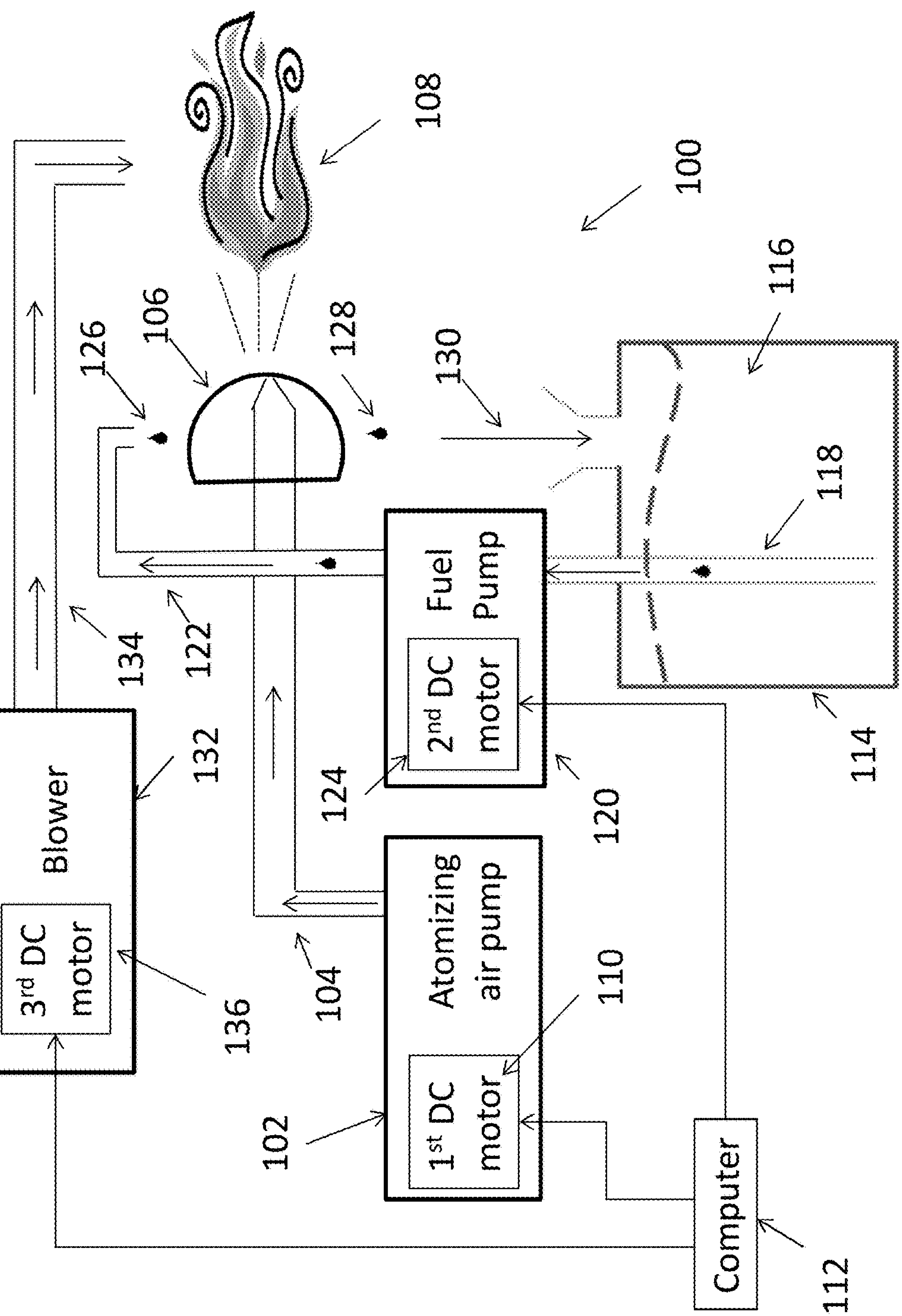
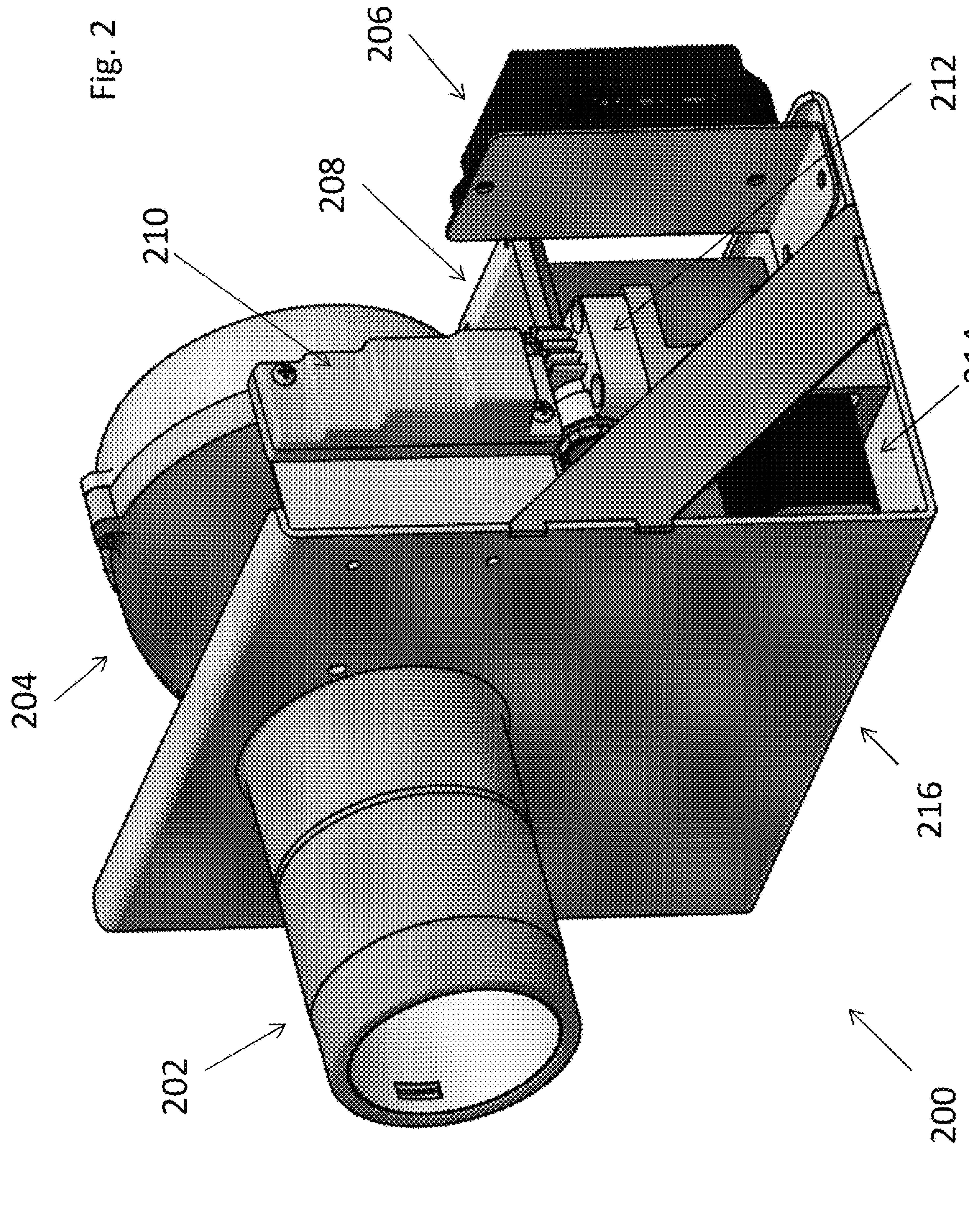

Blower
3rd DC motor
Atomizing air pump
1st DC motor
Fuel Pump
2nd DC motor
Computer
100
102
104
106
108
110
112
114
116
118
120
122
124
126
128
130
132
134
136

Fig. 2



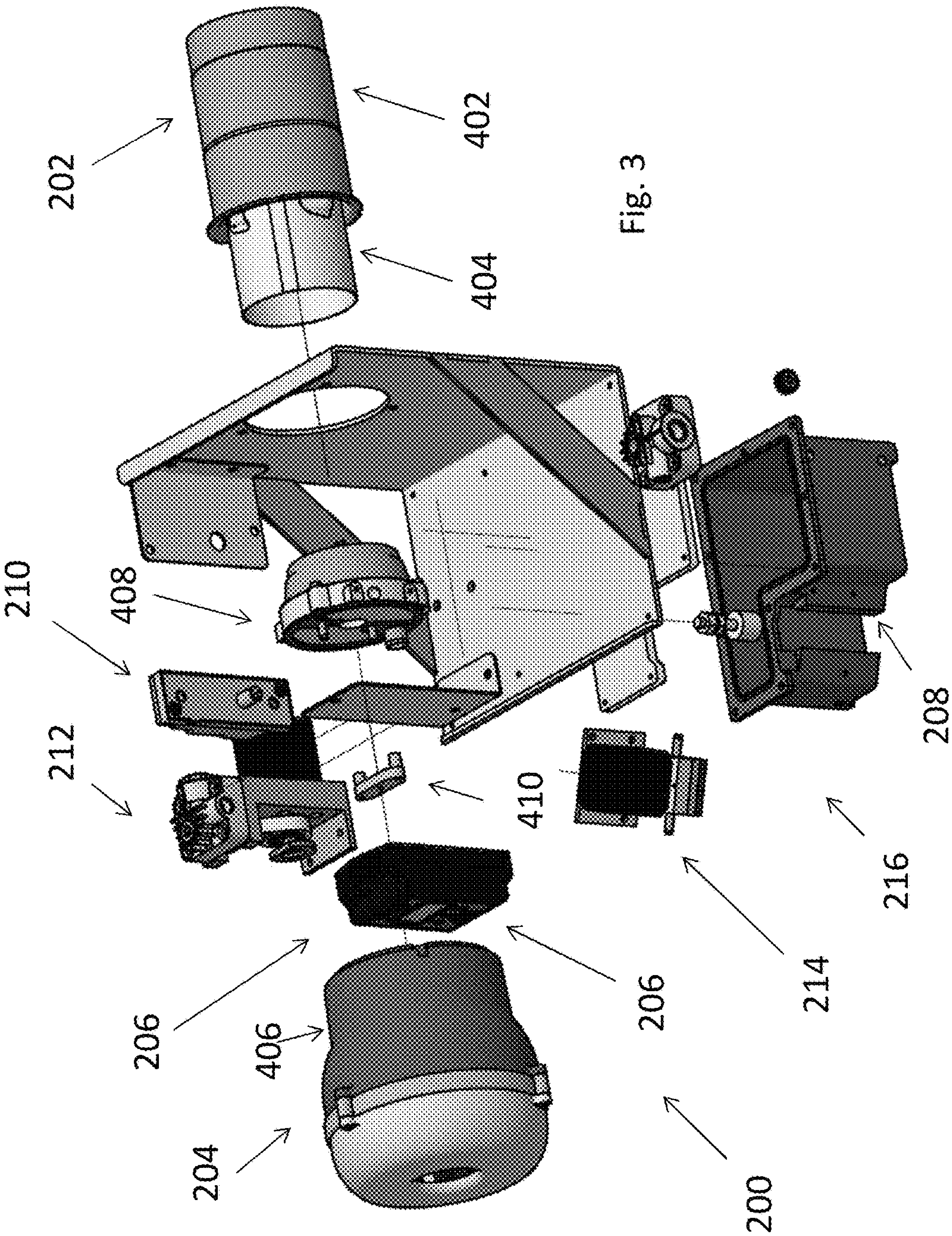


Fig. 3

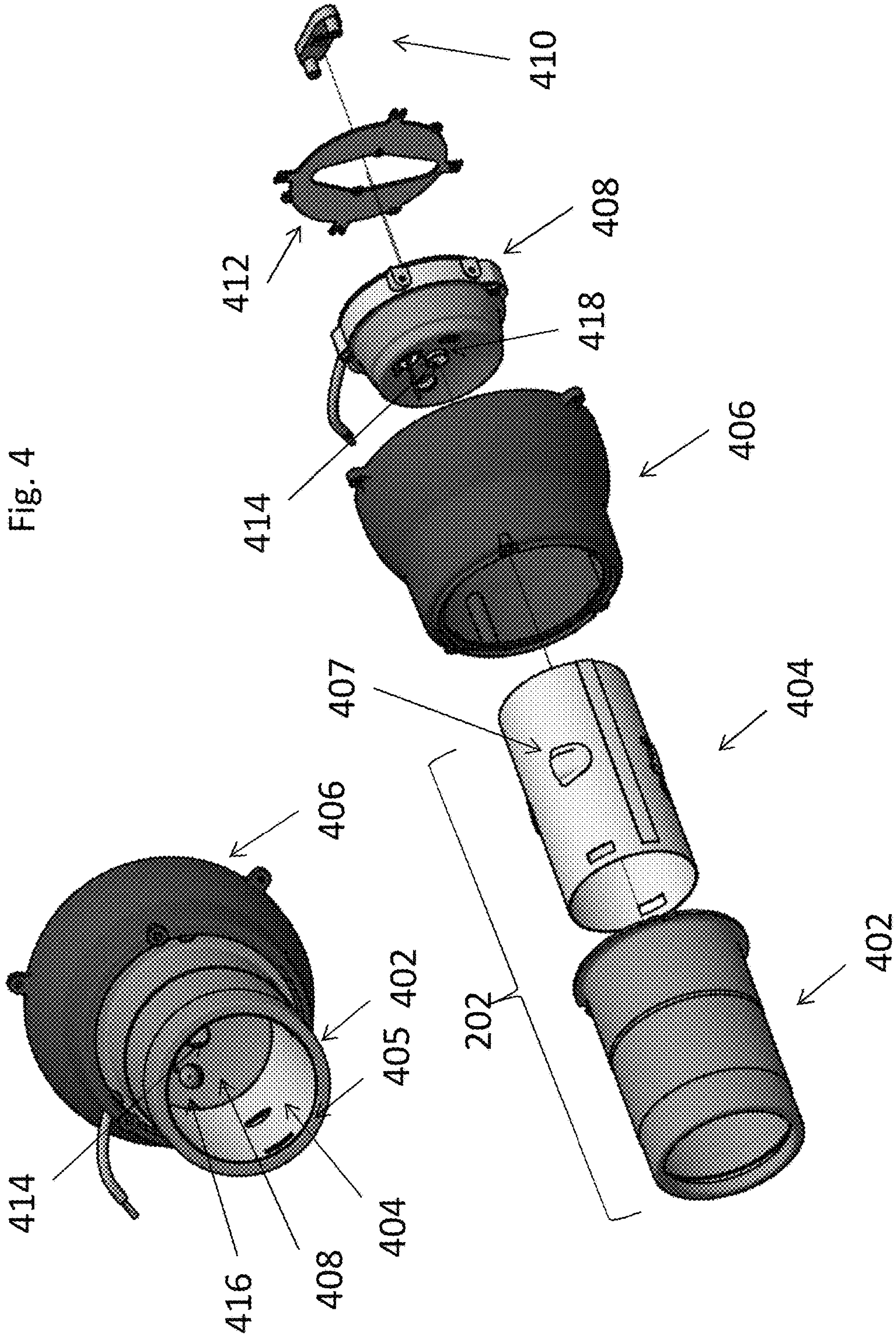

410
412
408
418
414
406
407
404
202
402
406
402
405
414
416
408
404

Fig. 4

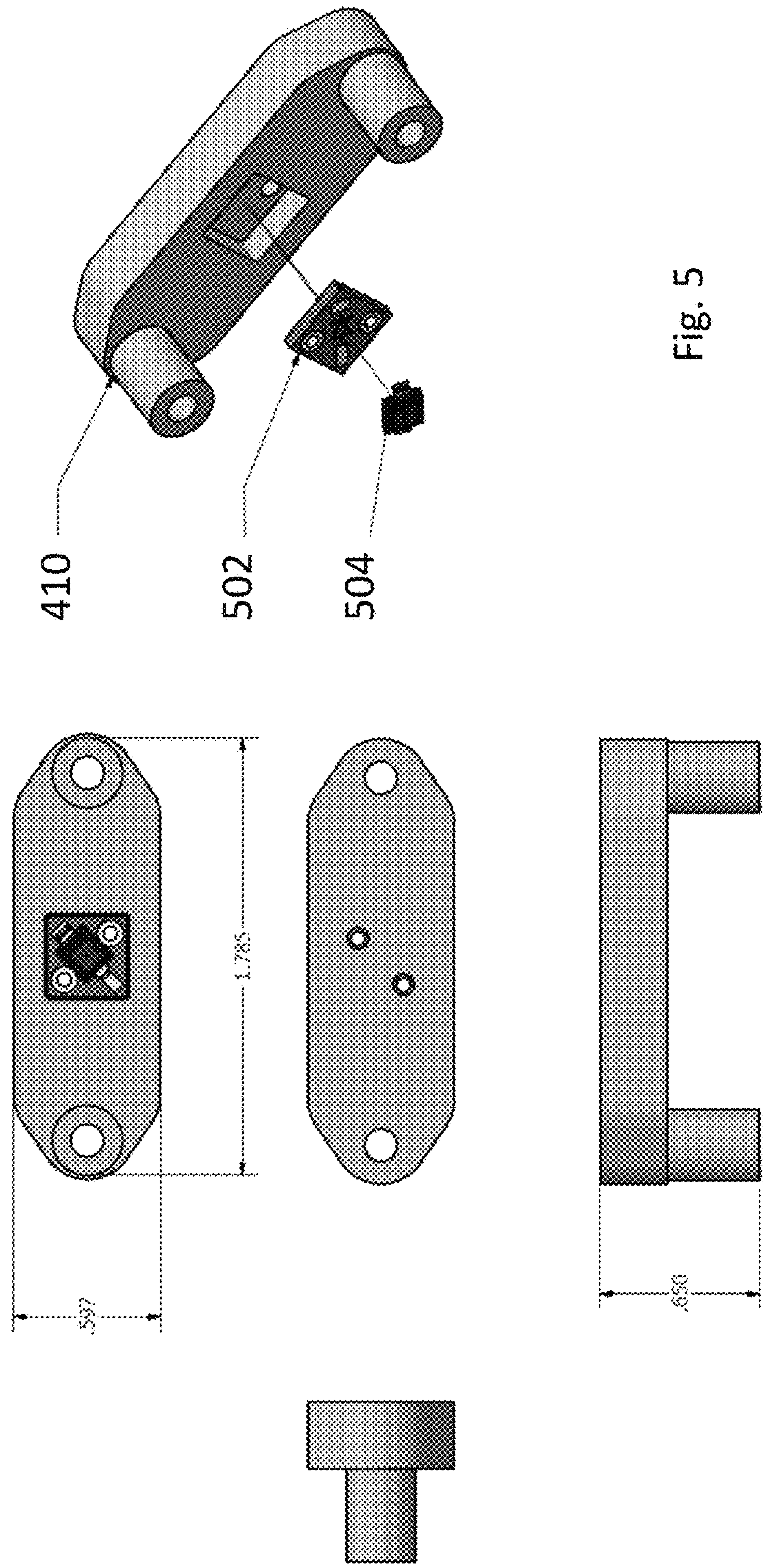


Fig. 5

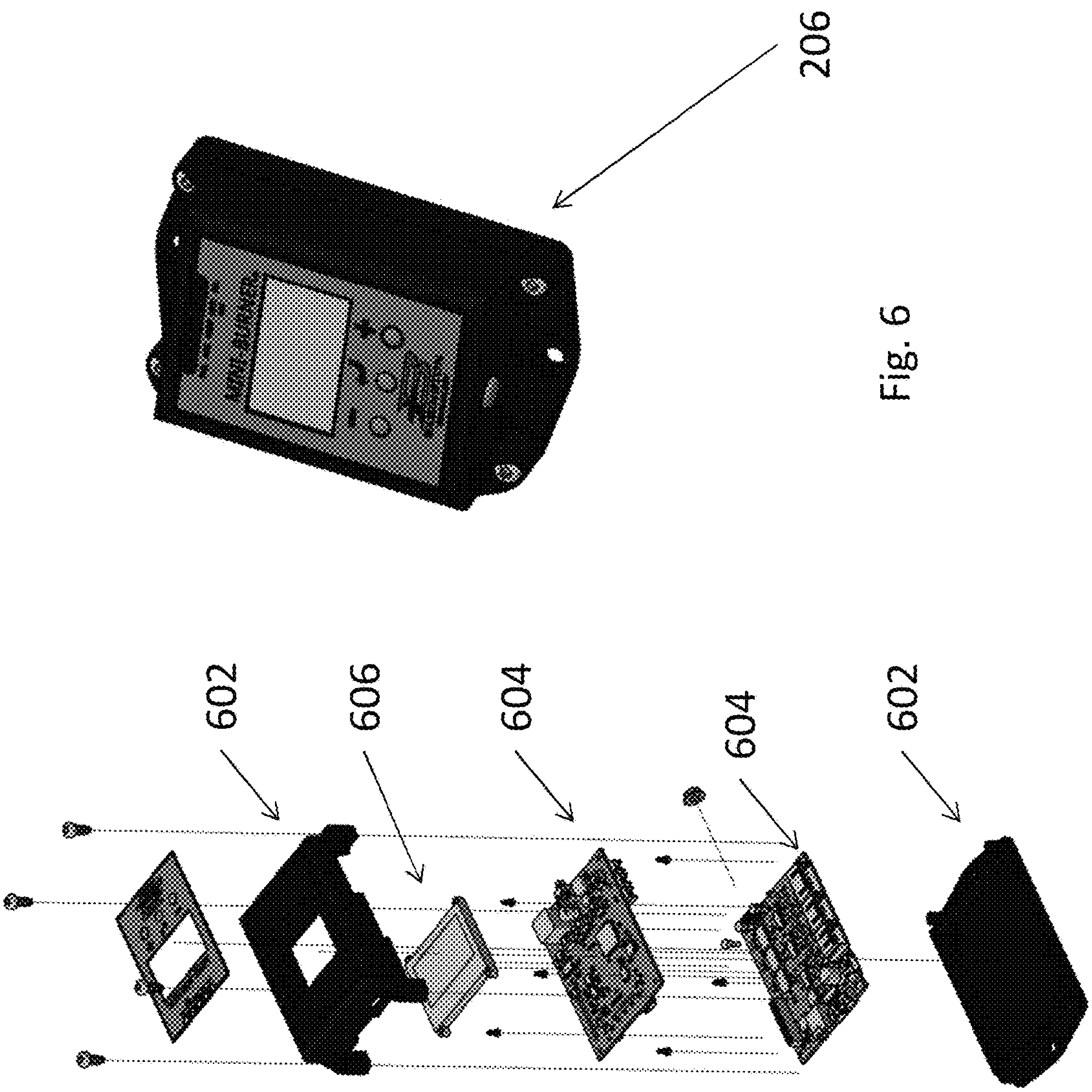


Fig. 6

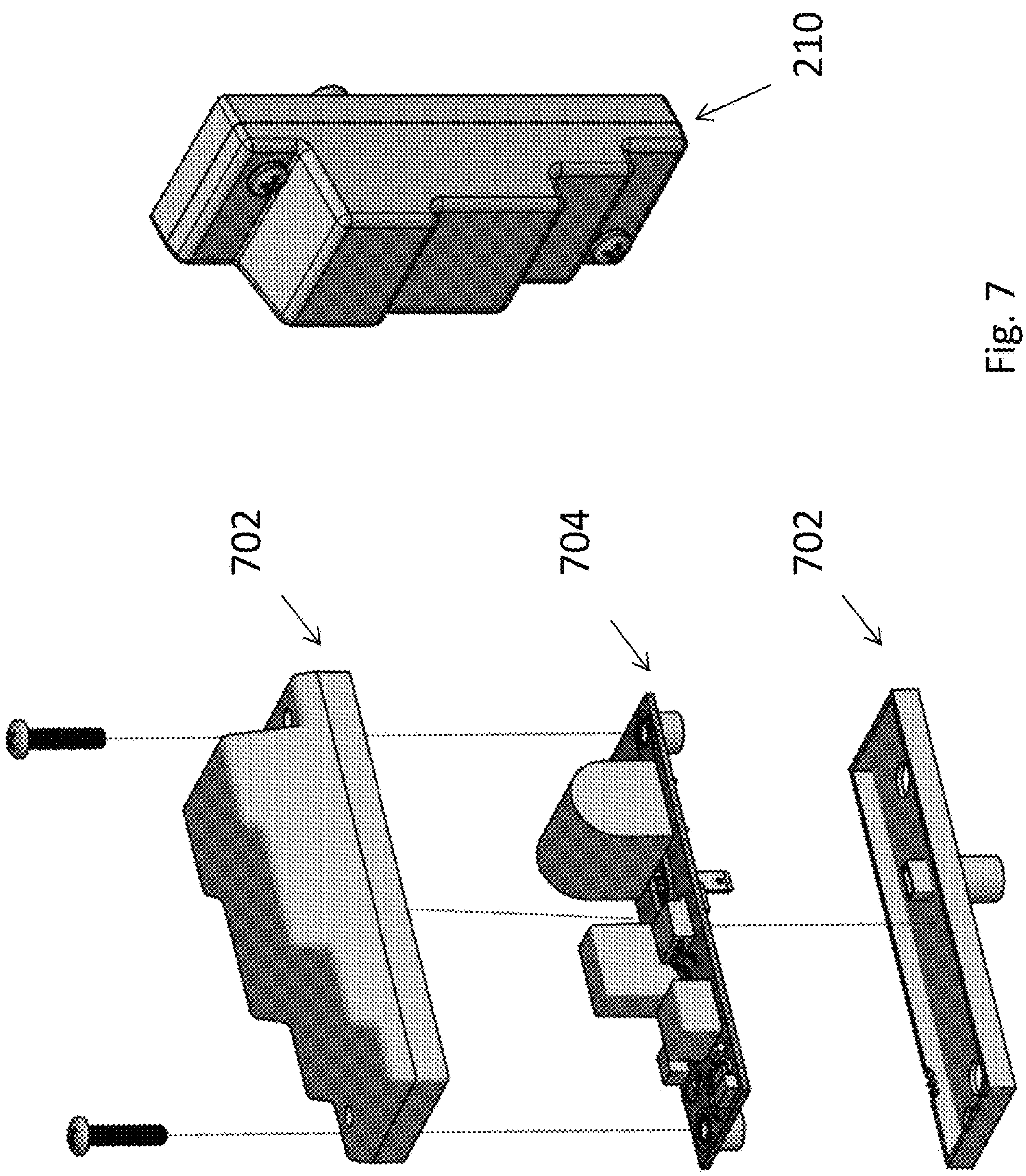


Fig. 7

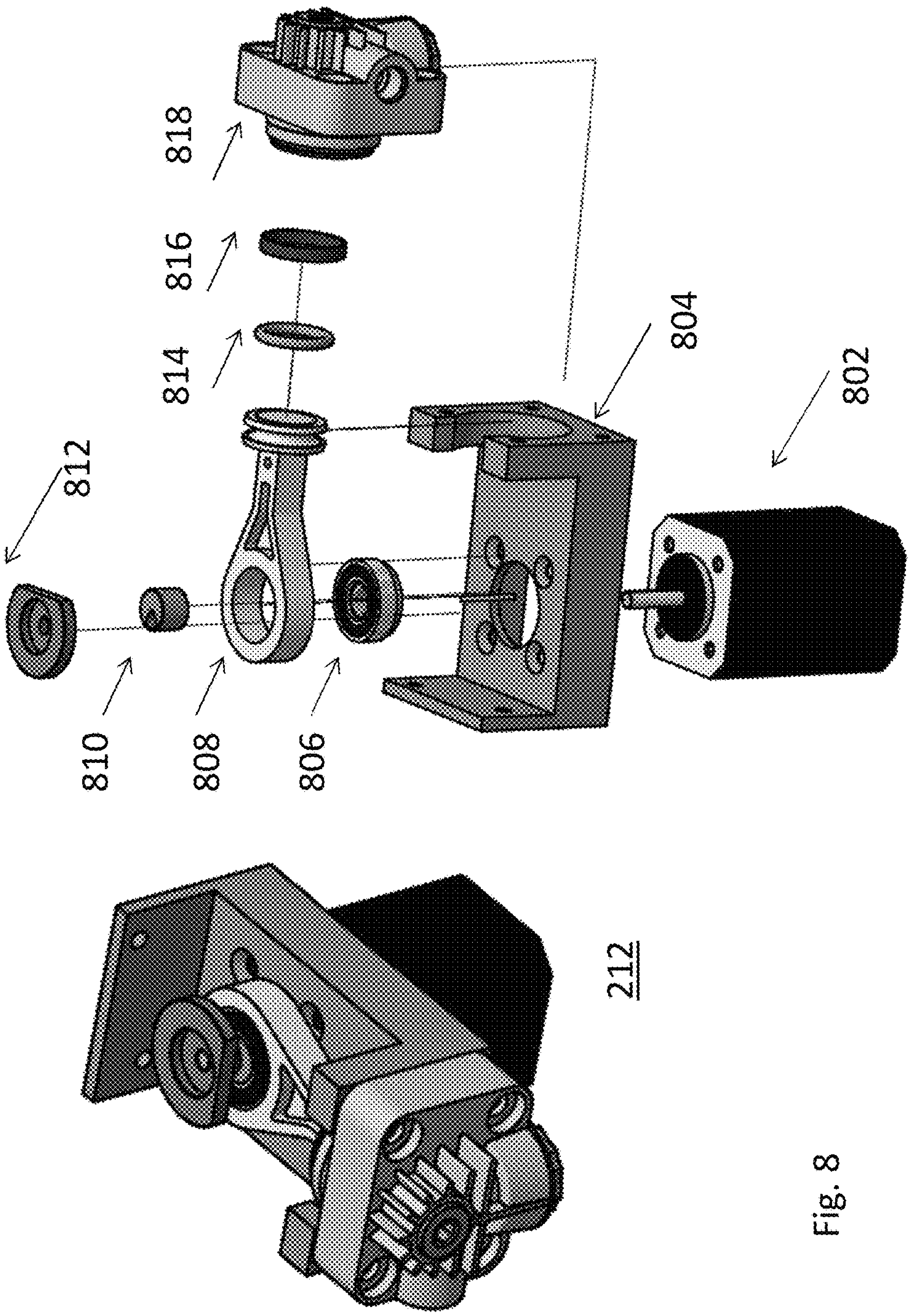


Fig. 8

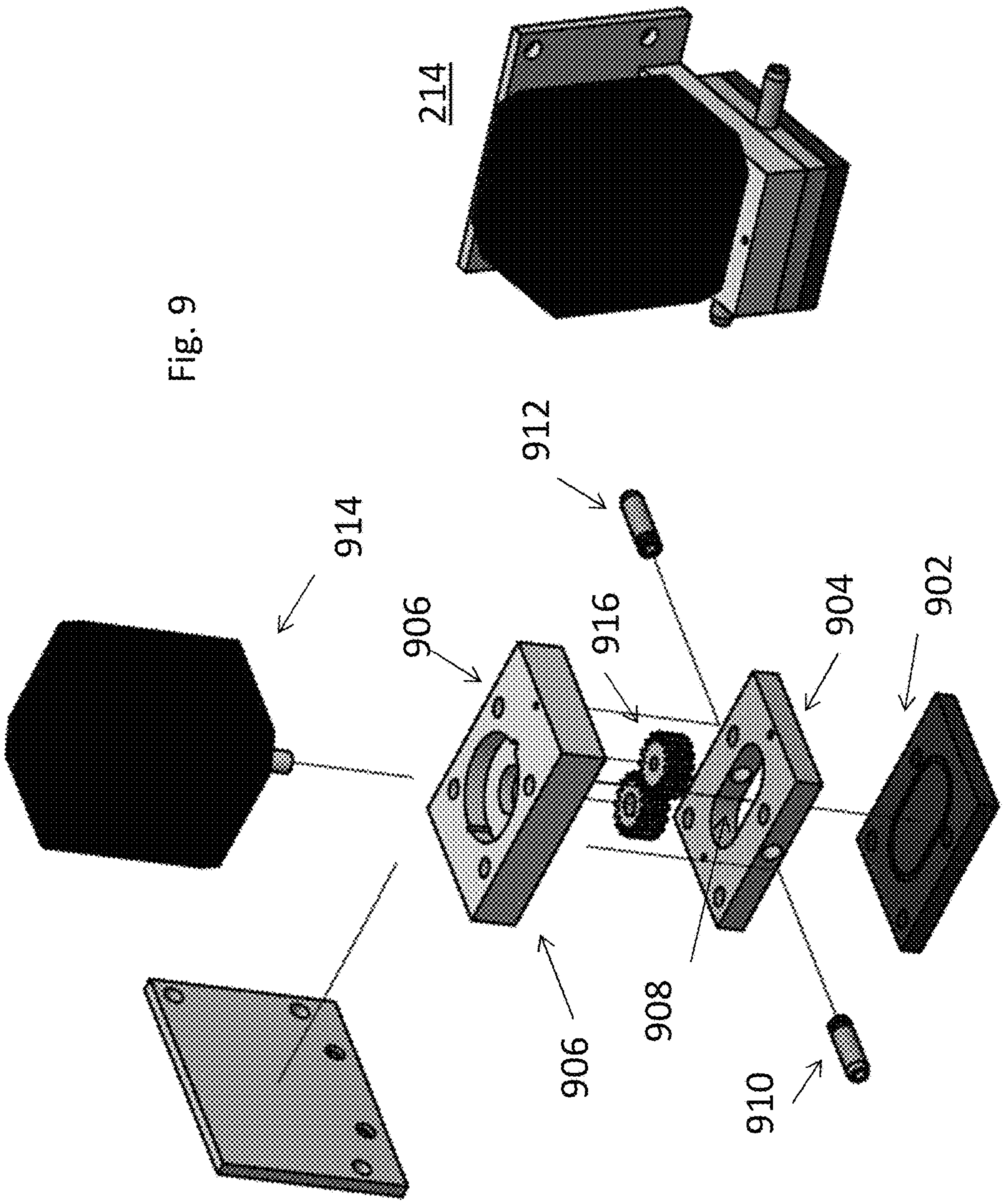


Fig. 9

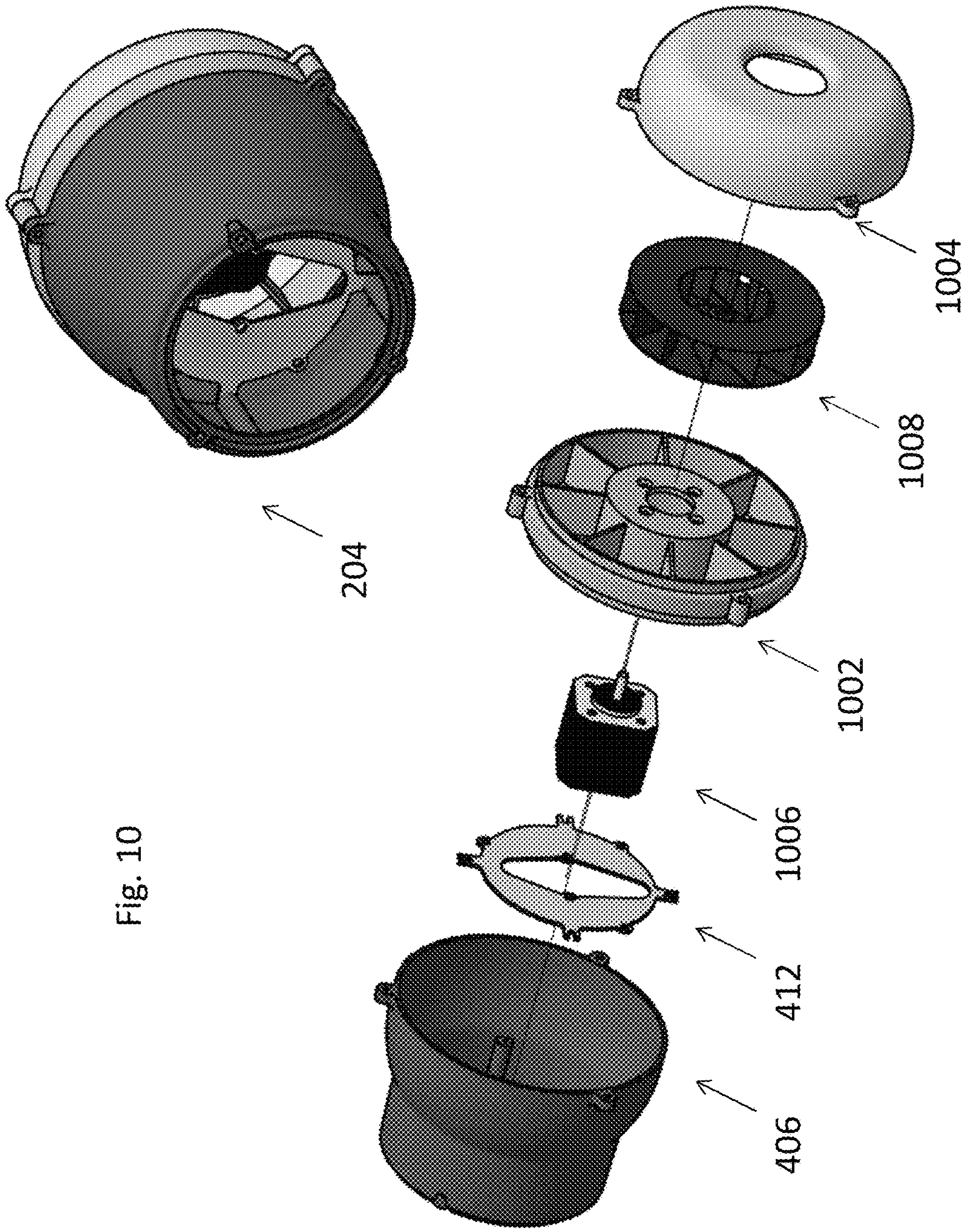


Fig. 10

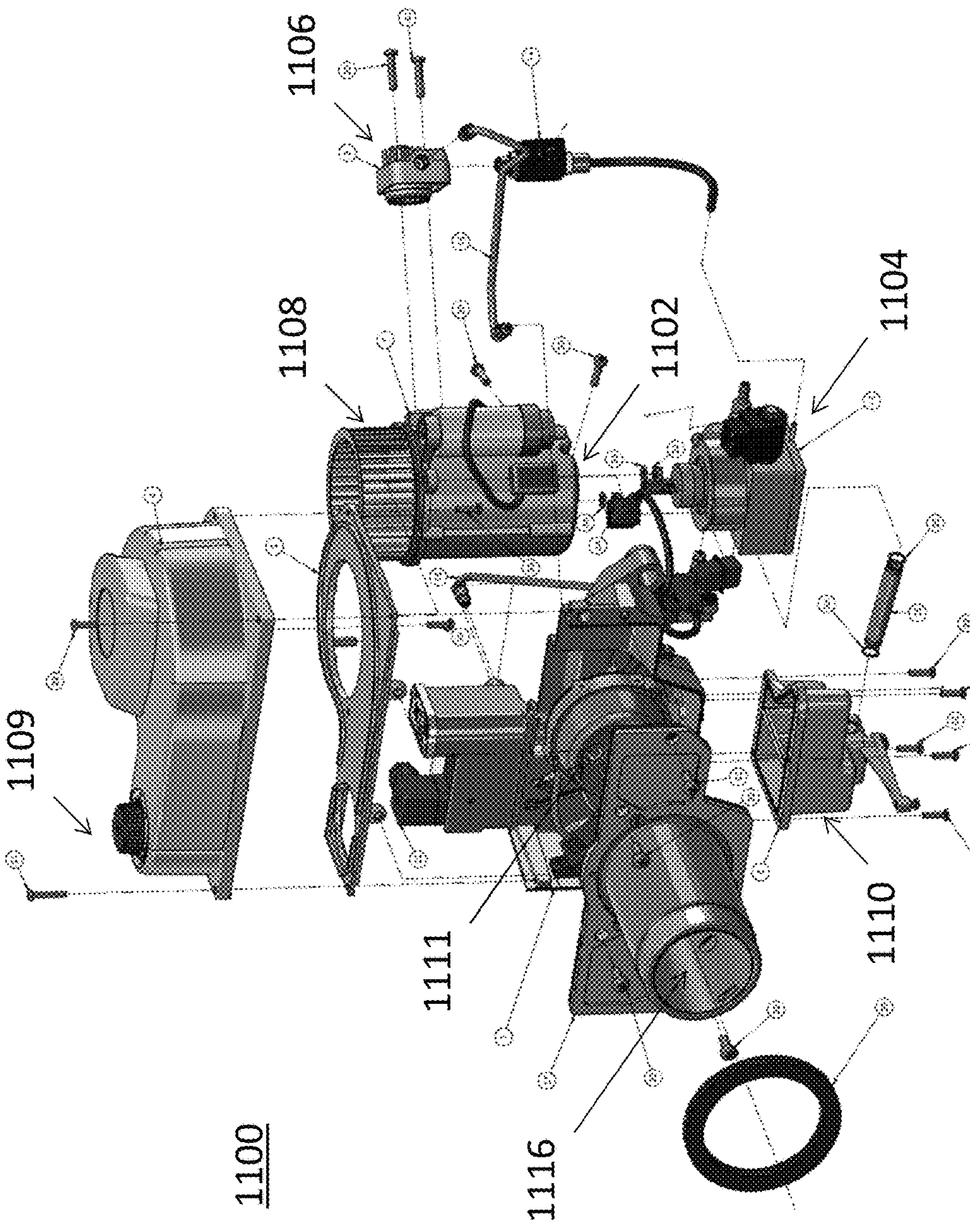


Fig. 11

PRIOR ART

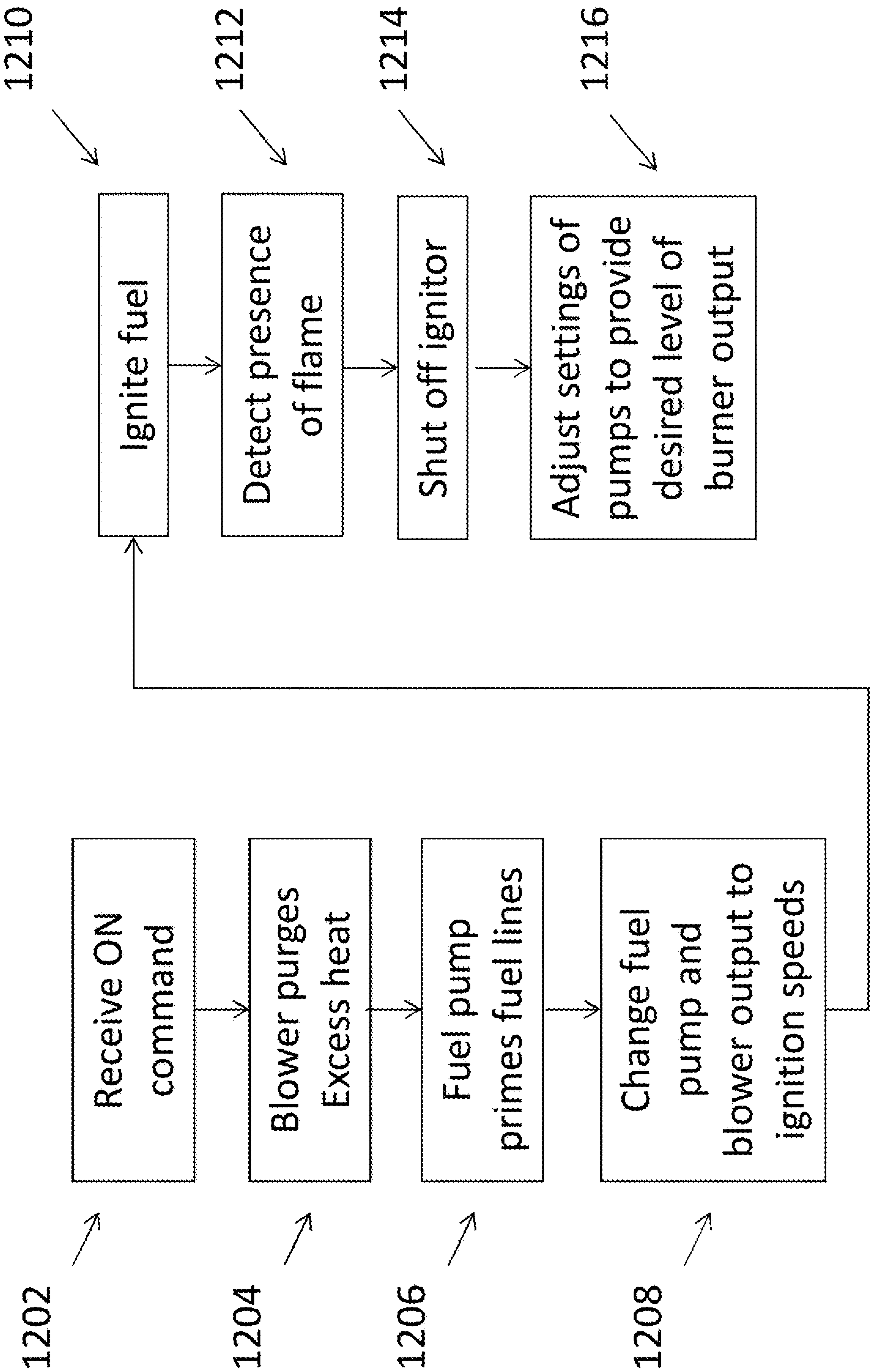

Receive ON command
Blower purges Excess heat
Fuel pump primes fuel lines
Change fuel pump and blower output to ignition speeds
Ignite fuel
Detect presence of flame
Shut off ignitor
Adjust settings of pumps to provide desired level of burner output
1202
1204
1206
1208
1210
1212
1214
1216

Fig. 12

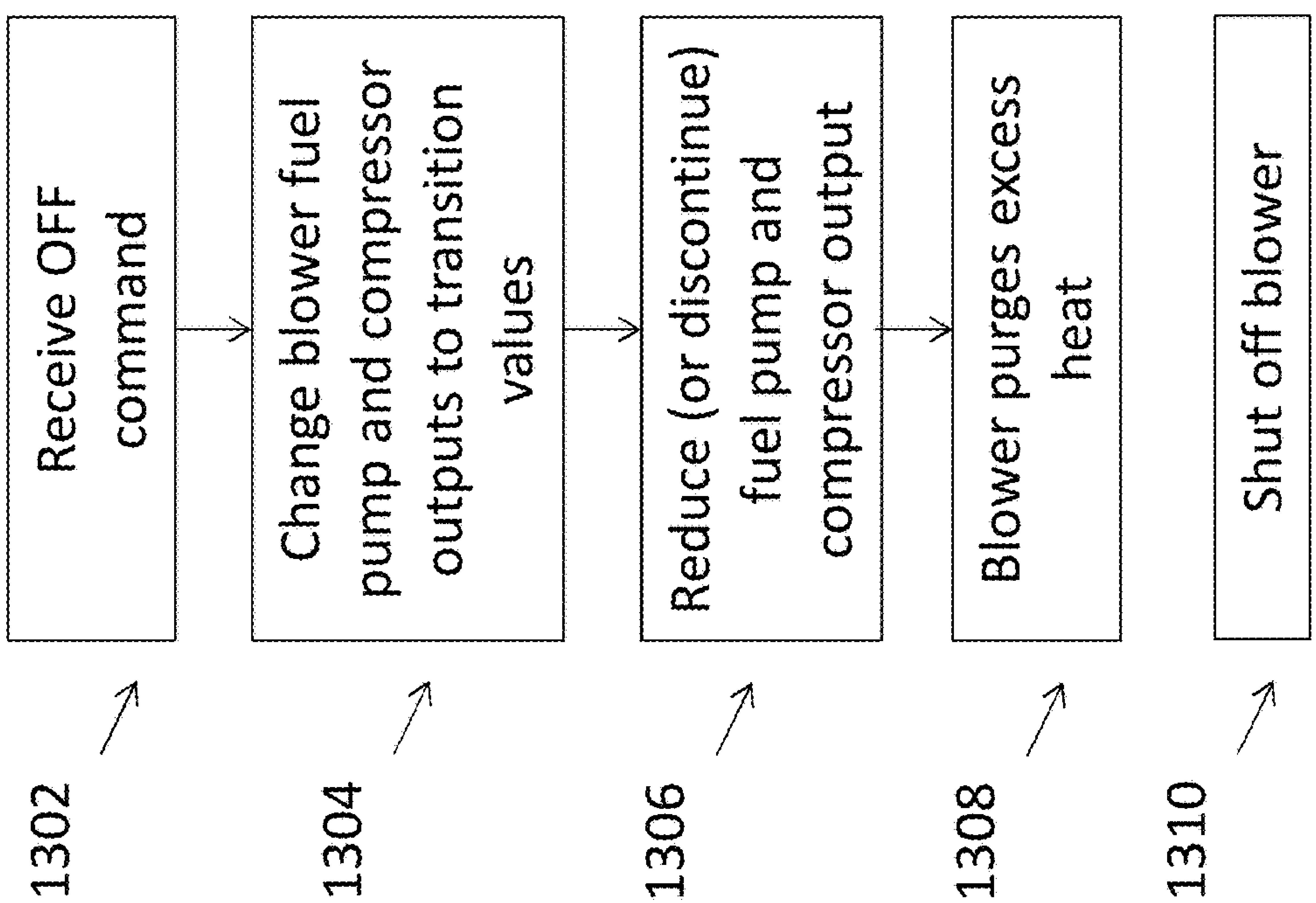

Receive OFF command
Change blower fuel pump and compressor outputs to transition values
Reduce (or discontinue) fuel pump and compressor output
Blower purges excess heat
Shut off blower
1302
1304
1306
1308
1310

Fig. 13

ATOMIZATION BURNER WITH FLEXIBLE FIRE RATE

CROSS REFERENCE TO RELATED APPLICATIONS

The instant application claims priority to U.S. Provisional Application 62/278,163, entitled ATOMIZATION BURNER WITH FLEXIBLE FIRE RATE, filed on Jan. 13, 2016, the contents of which is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

Various embodiments described herein relate generally to control of operating characteristics of a burner. More specifically, various embodiments described herein relate to an adjustable atomizing burner that can vary its output heat of a burner by dynamically adjusting the flows of fuel, combustion air and atomizing air during continuous operation.

BACKGROUND

Fuel burners built consistent with the Babington atomization principle are well known. The methodology mimics the atomization of water over a blowhole of a whale when the whale exhales. In the burner, a thin layer of fuel is poured over a convex surface that has a tiny air hole. Pressurized clean air is forced through the hole, creating a spray so fine that when burned, it creates no smoke, odor or carbon monoxide. By way of non-limiting example, the AIRTRONIC series of burners by BABINGTON TECHNOLOGY operate on this principle. Non-limiting examples of patents that disclose burners built according to this principle include, e.g., U.S. Pat. No. 4,298,338 entitled LIQUID FUEL BURNERS, U.S. Pat. No. 4,507,076 entitled ATOMIZATION APPARATUS AND METHOD FOR LIQUID FUEL BURNERS AND LIQUID ATOMIZERS, or U.S. Pat. No. 8,622,737 entitled PERFORATED FLAME TUBE FOR A LIQUID FUEL BURNER, the contents of which are incorporated herein by reference in their entireties, may be used.

Referring to FIG. **11**, an exploded view of the AIRTRONIC burner **1100** is shown. The burner includes a double shafted AC motor **1102** with a fixed speed. AC motor **1102** collectively drives a fuel pump **1104**, an atomizing air compressor **1106**, and a combustion air blower **1108**. Fuel pump **1104** delivers a stream of fuel from a reservoir **1110** to a point above convex heads (not shown) of an atomizing chamber **1111**. Air compressor **1106** injects air through a small hole in the heads spraying fuel as it flows over the hole of heads and projects the atomized fuel into flame tube **1116** (a process known as "atomization," thus air compressor **1106** being an "atomizing" air compressor). An ignitor (not shown) ignites the atomized fuel. Combustion air blower **1108** delivers a flow of air to the flame tube **1116** that combusts with the fuel to provide flame and heat, and to carry the heat and combusting fuel out of the flame tube **1116**.

In an atomization burner the flow of compressed air, combustion air and fuel must maintain a certain mixture relationship in order to properly combust the fuel. For example, a particular flow of atomizing air can only function with a certain range of fuel flow. Fuel flow in excess of that range is too thick to properly atomize, while fuel flow below that range is so thin that particles are too small to properly combust. Fuel flow above or below that range simply will not combust and/or will sub-optimally combust and generate byproducts (e.g., smoke, odor).

By nature of its design, the AIRTRONIC has constrained flexibility relative to this relationship. The fixed speed of the single AC motor **1102** drives fuel pump **1104**, combustion air blower **1108**, and atomizing air compressor **1106** at corresponding fixed maximum speeds. The flow of air from the compressor **1106** to atomizer heads (not shown) is not adjustable, which limits the potential range of fuel flow rate as noted above. The flow rate of fuel from fuel pump **1104** has some flexibility to reduce the fuel flow via an adjustable mechanical restrictor in the fuel flow pathway, but this is only accessible at the point of manufacture and is not adjustable by the consumer (absent disassembly). The flow of combustion air has some greater degree of flexibility, and is manually adjustable via a knob **1109** to physically restrict the air pathway from combustion air blower **1108** to flame tube **116**. This design combust fuel at a rate of 0.45-0.55 gallons per hour ("GPH"), although approximately 0.4-0.6 GPH is the theoretical range limit.

In recent years a market has emerged for portable cooking and heating appliances to cook for significant numbers of people at locations that do not have access to working kitchen facilities. For example, disaster relief operations need transportable kitchen appliances to bring to disaster zones and relief centers. Military units need kitchen appliances to support operations as personnel are deployed and relocate base camp. Restaurants and caterers may wish to cook at remote locations, such as beaches, wooded areas, street fairs, etc. A need therefore exists for portable and/or mobile kitchen appliances.

A difficulty with portable and/or mobile kitchen appliances is that it can be difficult to obtain different types of fuel in such circumstances as well as operate on reliable and sufficient electrical power. For example, if the transporting vehicle runs on gasoline and the cooking appliances run off propane, then there is a need to store, transport and maintain a supply of two different fuels. Gasoline and propane are also volatile fuels and dangerous to transport and store in the field. Organizations that provide such services therefore prefer that kitchen appliances and the vehicles that transport them consume the same type of fuel. Liquid distillate fuel, such as diesel as burned by the AIRTRONIC, is preferred. Applicants have several patents and applications to utilize a burner such as the AIRTRONIC in connection with portable cooking appliances, such as U.S. Pat. No. 8,499,755 entitled MOBILE KITCHEN, U.S. Pat. No. 7,798,138 entitled CONVECTION OVEN INDIRECTLY HEATED BY A FUEL BURNER, the contents of which are incorporated by reference herein in their entireties.

Use of the AIRTRONIC with portable cooking and/or heating appliances has a variety of drawbacks.

One drawback is that even at its minimal fuel flow rate the AIRTRONIC produces more heat than necessary for particular cooking apparatus. Some cooking appliances need to be overbuilt to withstand this heat output, which makes the appliance expensive to manufacture, heavy and energy inefficient. By way of non-limiting example, an oven as shown in U.S. Pat. No. 7,798,138 that could withstand the heat output of the AIRTRONIC weighs on the order of 800 lbs., which limits its portability options.

It is also difficult to change the temperature of the appliance. The overbuilt nature of the appliance needed to withstand the excessive heat output has a corresponding large specific heat, which makes the appliance slow to heat (wasting time and fuel) and slow to cool (potentially overcooking food). By way of non-limiting example, a chef may want to instantaneously reduce a stockpot cooker from a HIGH setting (e.g., to boil) to LOW setting (e.g., to simmer), but this takes several minutes even if the burner is turned off because the stockpot cooker itself has a high specific heat that retains the original high heat from the HIGH setting and only slowly cools.

It is also difficult to control the appliance temperature. The AIRTRONIC controls heat output via the "bang-bang" methodology, in that it is turned ON or OFF as appropriate to reach/maintain a desired temperature, also known as duty cycling. However, the AIRTRONIC takes 20-30 seconds to turn ON, and 90-120 seconds to turn OFF. By way of non-limiting example, in an oven preheated to 400 degrees, even if the burner is turned OFF when the oven reaches 400 degrees the burner continues to output heat. The oven will thus overshoot its preheat target to a higher temperature, and the specific heat of the appliance will slow the transition from the higher temperature to the desired preheat temperature.

The AIRTRONIC also consumes a considerable amount of power to operate because when active the components are at maximum flow speeds. Any adjustment in flow rates as noted above is due to physical impediments from restrictors in the flow pathways which can reduce flow but do not reduce power consumption. This level of power consumption is undesirable given the limited availability of power in the environments that would utilize portable cooking appliances.

DRAWINGS

Various embodiments in accordance with the present disclosure will be described with reference to the drawings, in which:

FIG. **1** shows an embodiment of the invention.

FIG. **2** shows an embodiment of the invention inside of a burner.

FIG. **3** is an exploded view of the embodiment of FIG. **2**.

FIG. **4** shows the atomizing chamber and flame tube of FIG. **2**.

FIG. **5** shows the support and photodiode of FIG. **2**.

FIG. **6** shows the microcomputer of FIG. **2**.

FIG. **7** shows the ignitor transformer of FIG. **2**.

FIG. **8** shows the compressor of FIG. **2**.

FIG. **9** shows the fuel metered pump of FIG. **2**.

FIG. **10** shows the blower of FIG. **2**.

FIG. **11** shows a prior art blower.

FIG. **12** is a flowchart of an embodiment of an OFF protocol.

FIG. **13** is a flowchart for an embodiment of an ON protocol.

DETAILED DESCRIPTION

In the following description, various embodiments will be illustrated by way of example and not by way of limitation in the figures of the accompanying drawings. References to various embodiments in this disclosure are not necessarily to the same embodiment, and such references mean at least one. While specific implementations and other details are discussed, it is to be understood that this is done for illustrative purposes only. A person skilled in the relevant art will recognize that other components and configurations may be used without departing from the scope and spirit of the claimed subject matter.

Several definitions that apply throughout this disclosure will now be presented. The term "substantially" is defined to be essentially conforming to the particular dimension, shape, or other feature that the term modifies, such that the component need not be exact. For example, "substantially cylindrical" means that the object resembles a cylinder, but can have one or more deviations from a true cylinder. The term "comprising" when utilized means "including, but not necessarily limited to"; it specifically indicates open-ended inclusion or membership in the so-described combination, group, series and the like. The term "a" means "one or more" unless the context clearly indicates a single element. The term "about" when used in connection with a numerical value means a variation consistent with the range of error in equipment used to measure the values, for which ±5% may be expected. "First," "second," etc., are labels to distinguish components or steps of otherwise similar names, but does not imply any sequence or numerical limitation.

As used herein, the term "front", "rear", "left," "right," "top" and "bottom" or other terms of direction, orientation, and/or relative position are used for explanation and convenience to refer to certain features of this disclosure. However, these terms are not absolute, and should not be construed as limiting this disclosure.

Shapes as described herein are not considered absolute. As is known in the burner art, surfaces often have waves, protrusions, holes, recess, etc. to provide rigidity, strength and functionality. All recitations of shape (e.g., cylindrical) herein are to be considered modified by "substantially" regardless of whether expressly stated in the disclosure or claims, and specifically accounts for variations in the art as noted above.

Referring now to FIG. **1**, a conceptual drawing of a burner **100** according to an embodiment of the invention is shown. Various components are connected by various pathways which can communicate air and/or liquid, such that all pathways are to be considered fluid pathways. It is to be understood for purposes of the conceptual nature of FIG. **1** that each "pathway" refers generically to a path by which a fluid moves from one point to of burner **100** to another, and does not imply any structure or location of the pathway; pathway may not even be a structure at all, as it may simply refer to the path travelled by fluid under gravity.

An atomizing air pump **102**, such as an air compressor, is provided to deliver clean air along a pathway **104** to an atomizing chamber supporting at least one atomizing head **106**. Atomizing head **106** has a convex surface with an orifice for spray dispensing fuel consistent with the Babington atomization principle. When fuel is poured over atomizing head **106** (as described below) and ignited, the combusting fuel will generate a flame plume **108** laterally in a flame tube (not shown in FIG. **1**). Atomizing air pump **102** includes a first adjustable speed DC motor **110**, which is controlled by a microcomputer **112**. Microcomputer **112** thus controls the flow speed of atomizing air provided by atomizing air pump **102**.

A fuel tank **114** is provided with fuel **116** for burner **100**, and is preferably located such that the top surface of fuel **116** is below atomizing head **106**. An inlet pathway **118** extends from fuel tank **114** to fuel pump **120**, and an outlet pathway **122** extends from fuel pump **120** to a point above atomizing head **106**. Fuel pump **120** includes a second speed adjustable DC motor **124**, which is controlled by microcomputer **112**. Microcomputer **112** thus controls the rate of fuel flow **126** delivered from fuel tank **114** to atomizing head **106**.

As is known in the art, the amount of fuel **126** delivered to atomizing head **106** may exceed the amount that is actually ignited by burner **100**. Excess fuel **128** falls by gravity along a return pathway **130** which directs the excess fuel **128** back into fuel tank **114**.

A blower **132** is provided to deliver clean air for combustion along a pathway **134** to the area in front of and around atomizing head **106**, preferably through the interior of the flame tube (not shown). Blower **132** includes a third speed adjustable DC motor **136**, which is controlled by microcomputer **112**. Microcomputer **112** thus controls the rate of combustion air to feed flame plume **108**.

The conceptual design of FIG. **1** may be implemented using various known structures for the components. The various fluid pathways may be constructed from hoses, pipes, or segments thereof connected together in a known manner. In the alternative, the various pathways could be drilled through solid material, such as a steel block. In yet another alternative, the various pathways could be partially defined in opposing blocks that form the pathways when the blocks are connected together. Combinations of the above, as well as other connection forming techniques may be used.

Referring now to FIGS. **2** and **3**, and non-limiting example of an embodiment of a burner **200** consistent with the concept of FIG. **1** is shown. Burner **200** includes a tube assembly **202**, a blower **204**, a microcomputer **206**, a fuel reservoir **208**, an ignition transformer **210**, an atomizing air compressor **212**, and a fuel metered pump **214**. The various components are supported by a housing **216**. Components are connected and mounted in manners known in the burner art and not further discussed herein.

Referring now to FIGS. **3** and **4**, the combustion chamber components of burner **200** are described in more detail. A tube assembly **202** includes an outer air tube **402**, an inner flame tube **404**, and an end cap **405**. Blower **204** blows combustion air into the gap between inner flame tube **404** and outer air tube **402**. Various air louvers **407** are provided in inner flame tube **404** to inject air in order to create a swirling combustion process inside inner flame tube **404**. Perforated air pathways (not shown) may be provided on the end cap **405** to permit passage of combustion air to cool flame tube assembly **202** and/or to shape combusting fuel as it emerges from the air tube flame tube assembly. The mechanics of the role of the combustion air and non-limiting examples of hole/louver placement are found in U.S. Pat. No. 8,622,737 entitled PERFORATED FLAME TUBE FOR A LIQUID FUEL BURNER, the contents of which is incorporated by reference in its entirety. However, the invention is not so limited, and any number or displacement of holes could be used to introduce air in the inner flame tube **404**.

An atomizing chamber **408** is rearward of the flame tube **404**, and receives fuel from fuel reservoir **208** (pathway not shown). A mounting ring **412** is mounted on the rear of atomizing chamber **408**. A support **410** is mounted in rearward of ring **412**, and supports a photodiode **504** (FIG. **5**). Atomizing chamber **408** includes an aperture **414** substantially at the center thereof, through which light from within the inner flame tube **404** can reach photodiode **504**. Atomizing heads as known in the art (e.g., head **106** in FIG. **1**) are rearward of lateral holes **418**. A front casing **406** (which is part of the blower **204**) has a flange that engages with the rear of outer air tube **402**. However, the invention is not so limited, and other forms of atomizing chambers may be used.

Referring now to FIG. **5**, the support **410** is shown in more detail. Support **410** supports a circuit board **502**, which in turn supports photodiode **504**. Photodiode **504** is part of a flame detection device described in more detail in U.S. Provisional Patent Application 62/274,879 discussed above.

However, the invention is not so limited, and other forms and/or locations of flame detection could be used.

Referring now to FIG. **6**, microcomputer **206** is shown in more detail. From hardware perspective, microcomputer **206** includes housing components **602**, circuit board components **604**, and display **606**. The circuit board components includes standard computer components such as at least one interface, display, processor, memory, wireless modem, jack for wired modem, etc. as is well known in the art and not discussed further herein. Microcomputer **206** also includes software and/or stored data to control the operation of burner **200** as discussed further herein. Software may be periodically updated to allow for new control protocols. The invention is not limited to the particulars of the implementation of microcomputer **206**, and the functionality therein may be in one unit as shown, multiple units, and/or work in cooperation with an external computer.

Referring now to FIG. **7**, ignition transformer **210** is shown in more detail. Ignition transformer **210** includes housing components **702** and a printed circuit board **704**. As is known in the burner art, ignition transformer **210** converts available external power (AC or DC, not shown) into the power to generate a spark that it provides to electrodes (not shown) in atomizing chamber **408**. However, the invention is not so limited, and other forms of ignitors may be used.

Referring now to FIG. **8**, atomizing air pump **212** is shown in more detail. Atomizing air pump **212** includes a DC motor **802** below a frame **804**, a bearing **806**, a piston **808**, a piston bushing **810**, a counterweight **812**, an O-ring **814**, a piston ring **816**, and a compressor cylinder head **818**. However, the invention is not so limited, and other forms of atomizing air pumps may be used. DC motor **802** drives piston **808** to provide clean air to the holes in atomizing heads to spray fuel.

Referring now to FIG. **9**, fuel pump **214** is shown in more detail. A bottom base plate **902**, a support plate **904** and a top plate **906** define an inner chamber **908** with fluid inlet and outlet pathways **910** and **912**. A DC motor **914** drives gears **916** within inner chamber **908** to draw fluid from fuel reservoir **208** to atomizing chamber **408**. However, the invention is not so limited, and other forms of fuel pumps may be used.

Referring now to FIG. **10**, blower **204** is shown in more detail. The outer shell is defined by front casing **406**, and intermediate support **1002**, and rear casing **1004**. A DC motor **1006** drives a blower wheel **1008** to draw air through an opening in rear casing **1004** and blows it out front casing **406** into the space between inner and outer tubes **402** and **404** as discussed above. Intermediate support provides a mounting point for both motor **1006** and blower wheel **1008**.

The above embodiment combusts fuel in a manner consistent with the Babington atomization principle. Fuel pump **214** delivers fuel over the atomizing heads **416**. Atomizing air pump **212** pumps air through holes in the atomizing heads, spraying the delivered fuel into the inner flame tube **404**. Blower **204** delivers combustion air into the inner flame tube **404** to facilitate combustion of the fuel. Ignition transformer **210** ignites the fuel spray to induce combustion.

Microcomputer **206** is connected to the three DC flow motors **802**, **914**, and **1006**. As DC motors, their speed is adjustable to adjust the flow rates of fuel, atomizing air and combustion air. Microcomputer **206** can thus control the speeds of the three flow parameters that define how much heat burner **200** produces, such as by controlling the amount of voltage applied or rate of pulsing of the motors. The invention is not limited to the manner in which the microcomputer **206** controls the speed of the DC motors.

As noted above, in an atomization burner the flow of compressed air, combustion air and fuel must maintain a certain relationship in order to properly combust the fuel. Microcomputer **112** is accordingly programmed with protocols to set those three flow parameters to meet the desired goal of the system, which may be a target operating temperature of an appliance (e.g., 350 degrees) or certain heat output (e.g., low, medium, high and gradations there between). Preferably this is done algorithmically and/or through a database of parameters to meet the specific needs of the environment, such as the type of appliance, type of fuel, external temperature, presence of rain, etc. For example, the amount of heat needed to heat a stockpot cooker is different than to heat an oven, the latter being larger and traditionally operating at higher temperatures. Microcomputer could thus maintain one set of operating protocols for an oven, another for a stockpot cooker, etc.

The protocols could be specific, e.g., to reach a desired heat output set all three flow parameters to a certain value. The protocols may be adaptive, in that they are based on the current state of the burner relative to the target state; for example the flow parameters to heat an oven to 400 degrees from a starting state of room temperature may be different than if the starting state (or current state) of the oven is already at 300 degrees. The protocols may work on the "bang-bang" methodology, or may adjust the flow rates in response to current or predicted conditions to "soft land" at the target output to minimize overshoot. The protocols may call for certain flow parameters to use higher heat output under cold or rainy conditions or decrease heat output under hotter conditions. Other protocols may also be used. Protocols based on combinations of factors may also be used. The embodiments are not limited to the nature of the protocols used.

Microcomputer **206** can be programmed to implement specific turn ON and turn OFF protocols for the burner **200**.

With respect to the ON protocol, the parameters for flow of atomizing air, combustion air and fuel may be different for ignition of the fuel as compared to running the blower. An ON protocol implemented by microcomputer **112** could thus be to set the flow parameters to a combination particular to ignition, detect the presence of flame via the flame detector, and then set the flow parameters to a combination particular to running the burner **200**. Some or all of the parameters may be the same or different for ignition relative to running.

A non-limiting example of an ON protocol with respect to burner **100** of FIG. **1** is shown in FIG. **12**, as implemented by microcomputer **112** to a adjust the speed of motors **110**, **124** and **136**. Beginning with an OFF state in which all motors are inactive, an ON command is received at step **1202**. At step **1204** the blower purges any residual heat from burner **100**, preferably the setting the motor **136** to its maximum speed (e.g., 6500 rpm) for a period of time (e.g., 30) seconds or until the ambient burner temperature drops below a certain value. After completion of step **1204** then at step **1206** the fuel pump **120** primes the fuel to the atomizing head **106**, preferably by starting with a low speed of motor **124** (e.g., 600 rpm) and increasing gradually to a fuel priming speed (e.g., 1200 rpm) for a period of time (e.g., 15 seconds); the objective is to drive all of the air out of the fuel lines and to adequately wet the atomizing head **106**. At step **1208**, the blower and fuel pump outputs are reduced to a speed to induce ignition (e.g., motor **124** to 400 rpm and motor **136** to 3500 rpm). After the burner reaches the new speeds, at step **1210** the fuel is ignited by turning on the ignitor and setting motor **112** of atomizing air compressor **102** to an ignition speed (e.g., 2200 rpm). At step **1212** the presence of flame is detected in flame tube (e.g., through the methodology of U.S. 62/274,879, although the invention is not so limited). In response to confirmation of flame the ignitor is shut off at step **1214**, and the various flow parameters of burner **100** are changed to output the desired amount of heat.

With respect to a non-limiting example of an OFF protocol, flow parameters would continue (i.e., not be set to zero) but at least one of the flow parameters would be changed to preferably reduce the heat output, produce minimal pollution during the shutdown protocol, and impose minimal stress on the system. The change may increase or decrease the different flow parameters as needed to transition a shutdown transition state. After the transition state is reached the parameters are maintained for a first period of time to at least allow the transition state to stabilize. At the end of the first period of time the atomizing air and fuel flow would be stopped (e.g., by electric braking of the motors, and either simultaneously or in succession) while the flow of combustion air continues, possibly at different levels; the flow of combustion air is no longer for combustion purposes, but instead is preventing heat from building up in burner **200**. After a second period of time, the combustion air flow is stopped (e.g., by electric breaking of the motor). The first and second times may be predetermined, or based on reaching detected target conditions. In addition and/or the alternative, the protocol may include reversing the flow of fuel (e.g., via reverse operation of motor **914**) to clear the fuel lines.

A non-limiting example of an OFF protocol with respect to burner **100** of FIG. **1** is shown in FIG. **13**, as implemented by microcomputer **112** to adjust the speed of motors **110**, **124** and **136**. Beginning with an ON state in which all motors are active, an OFF command is received at step **1302**. At step **1304** the speed of motors **110**, **124** and **136** changes to predefined non-zero transition levels (e.g., 1200 rpm for the atomizing air pump **102**, 300 rpm for the fuel pump **120**, and 3000 rpm for the blower **132**) and maintained for a period of time (e.g., 1-3 seconds) to allow burner **100** to stabilize. At step **1306**, atomizing air pump **102** and fuel pump **120** reduce speed (e.g., discontinue of power flow or electric braking, such reduction preferably being to zero rpm to discontinue flow entirely); preferably the reduction is simultaneous, but it may be sequential. At step **1308**, blower continues to operate to remove excess heat, preferably by increasing motor **136** to maximum (e.g., 6500 rpm) and maintaining air flow for a period of time (e.g., 2 minutes) or until the burner or appliance heated by the burner drops to a desired temperature 150 F. When the target time/temperature is reached, at step **1310** blower **132** shuts down; air pump **102** and fuel pump **120** would also shut down at this point if they have not previously done so.

The above embodiments overcome various drawbacks over the prior art AIRTRONIC burner, particularly in connection with portable cooking appliances.

For example, the minimum fuel flow rate for burner **200** is about 0.155 GPH, which is on the order of 40% of the heat output and fuel consumed compared to the AIRTRONIC. The embodiments herein can thus generate less heat, and consume less fuel, than the AIRTRONIC. The embodiments also consume less power because unlike the AIRTRONIC the motors **802**/**914**/**1006** need not operate at maximum output. The current variable firing rate range of 0.155 GPH to 1.0 GPH far exceeds the operating ranges of the prior art AIRTRONIC burner.

Since the embodiments herein can generate less heat than the AIRTRONIC, it can be used with lighter/smaller cooking appliances, and/or enables off-grid self-powered capabilities. By way of non-limiting example, as discussed above an oven for use with the AIRTRONIC would be overbuilt to withstand the heat output and weighs on the order of 800 lbs., with a corresponding high specific heat that makes the oven slow to heat or cool. Embodiments herein can be used with an oven on the order of 200-250 lbs., which is cheaper to build, consumes less fuel to transport, easier to relocate on site, and can heat or cool much faster than its larger counterpart.

The embodiments herein can also operate without reliance on the "bang-bang" methodology, instead reducing the fuel flow rate as the target temperature is approached. This reduces the likelihood of overshooting the target temperature. Embodiments may precision load match the heat output of the burner with the load requirement of the appliance.

The embodiments herein also eliminate any need for a second blower in the appliance to prevent heat buildup. As noted above, when the AIRTRONIC is turned OFF, heat must be prevented from building up inside the flame tube; since the main blower is not active, a secondary blower is often present to provide venting air for 90-120 seconds. In the embodiments herein, blower **132** can continue to run during that period to provide the venting air. The embodiments herein thus remove any need for the secondary blower (although such a secondary blower may nonetheless still be present).

The embodiments herein are directed to use of burner with cooking appliances. However, the invention is not so limited, and other environments could be used.

The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense. It will, however, be evident that various modifications and changes may be made thereunto without departing from the broader spirit and scope of the invention as set forth in the claims.

What is claimed is:

1. A method for turning an atomizing burner from an ON state to an OFF state, the burner having independently controllable flows of atomizing air, combustion air, and fuel flow, the burner in the ON state having flow values of burner parameters including flow of atomizing air, flow of combustion air, and fuel flow, the method comprising:

changing, in response to an OFF instruction, flow of at least one of the flow of atomizing air, combustion air and/or fuel to a lower non-zero value;

first discontinuing, after a first period of time since the changing, flow of fuel and flow of atomizing air;

maintaining, for a second period of time since the first period of time, flow of combustion air;

second discontinuing, after the maintaining, flow of combustion air;

wherein the maintaining prevents buildup of excess heat inside the burner during the transition to the OFF state.

2. The method of claim **1**, wherein the first discontinuing discontinues flow of fuel and flow of atomizing air simultaneously.

3. The method of claim **1**, wherein the first discontinuing comprises discontinuing one of flow of fuel and flow of atomizing air and then discontinuing the other of flow of fuel and flow of atomizing air.

4. The method of claim **1**, wherein the first discontinuing comprises electrical braking of a motor driving flow of fuel and a motor driving flow of atomizing air.

5. A method for turning an atomizing burner from an ON state to an OFF state, the burner having independently controllable flows of atomizing air, combustion air, and fuel flow, the burner in the ON state having burner parameters including flow of atomizing air, flow of combustion air, and fuel flow, the method comprising:

changing, in response to an OFF instruction, flow of atomizing air, combustion air and fuel to predetermined flow levels;

first maintaining, in response to the changing, the predetermined flow levels for a first period of time;

first reducing, after the first maintaining, flow of fuel;

second reducing, after the first maintaining, flow of atomizing air;

increasing, after the first maintaining, flow of combustion air;

third reducing, after the increasing, flow of combustion air;

wherein the burner continues flow of combustion air between the increasing and the third reducing to prevent the buildup of excess heat inside the burner during transition of the burner to the OFF state.

6. The method of claim **5**, wherein the changing comprises slowing the flow of all of the flow of atomizing air, combustion air and fuel.

7. The method of claim **5**, where the changing comprising slowing the flow of at least one of the flow of atomizing air, combustion air and fuel and increasing the flow of a different at least one of the flow of atomizing air, combustion air and fuel.

8. The method of claim **5**, wherein the first reducing comprises discontinuing flow of fuel, the second reducing comprises discontinuing the flow of atomizing air, and the third reducing comprises discontinuing flow of combustion air.

9. The method of claim **5**, wherein the first and second reducing are simultaneous or sequential.

10. The method of claim **5**, wherein the increasing comprises increasing a speed of a blower of combustion air to a maximum speed.

11. The method of claim **5**, wherein the third reducing is in response to either (a) a predetermined time after the increasing, or (b) a component of the burner or an appliance heated by the burner falls below a predetermined temperature.

12. An atomizing burner having an atomizing head and a flame tube, comprising:

a first DC fuel motor adapted to deliver fuel flow to the atomizing head;

a second DC atomizing air motor adapted to provide to an opening in the atomizing head where the atomizing air will atomize the fuel;

a third DC combustion air motor adapted to deliver combustion air to the flame tube to aid in combustion of atomized fuel;

a controller comprising a combination of hardware and software programmed to turn the burner ON and OFF, wherein to turn the burner OFF the program will at least discontinue flow of atomizing air and fuel while continuing flow of combustion air to prevent the buildup of excess heat in the flame tube.

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